(12) UK Patent Application (19) GB (11) 2 330 007 (13) A

(43) Date of A Publication 07.04.1999

(21) Application No 9720994.4

(22) Date of Filing 03.10.1997

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(51) INT CL^6
H01Q 1/08 , F16H 21/00 // B64G 9/00

(52) UK CL (Edition Q)
H1Q QKC
F2K K4B5

(56) Documents Cited
US 5243803 A **US 4896165 A**

(58) Field of Search
UK CL (Edition P) **F2K K4B5 K4B9 , H1Q QKC**
INT CL^6 **B64G 9/00 , F16H 21/00 21/02 21/04 21/46 , H01Q 1/08 1/12 1/28**
On-line: WPI, CLAIMS, EPODOC, JAPIO

(54) Abstract Title
Expandable support ring

(57) Expandable support rings are employed for large diameter antenna reflectors, to assist in unfurling the reflector in space. An expandable support ring 2 for a deployable antenna reflector comprises a plurality of pairs, e.g. 4, 5 of struts 6, 7 and 8, 9, which are linked to each other so that the ring can expand by pantograph action. Respective hinge means e.g. 12, 13, 14, 15 are provided to link an end of each strut of each pair to an end of a strut of an adjacent pair. Each hinge means includes a pair of tapered surfaces e.g. 18, 19, (Fig. 5 not shown) which maintain rolling contact as the ring expands. The invention provides an arrangement capable of low fiction and low backlash during expansion.

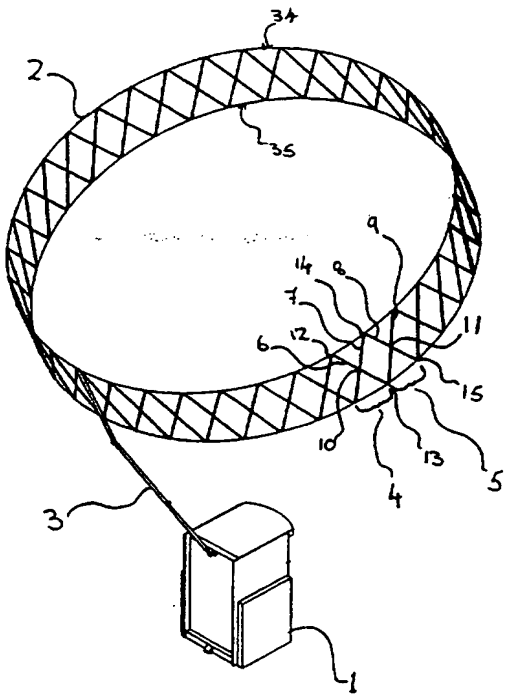

FIG. 2

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995

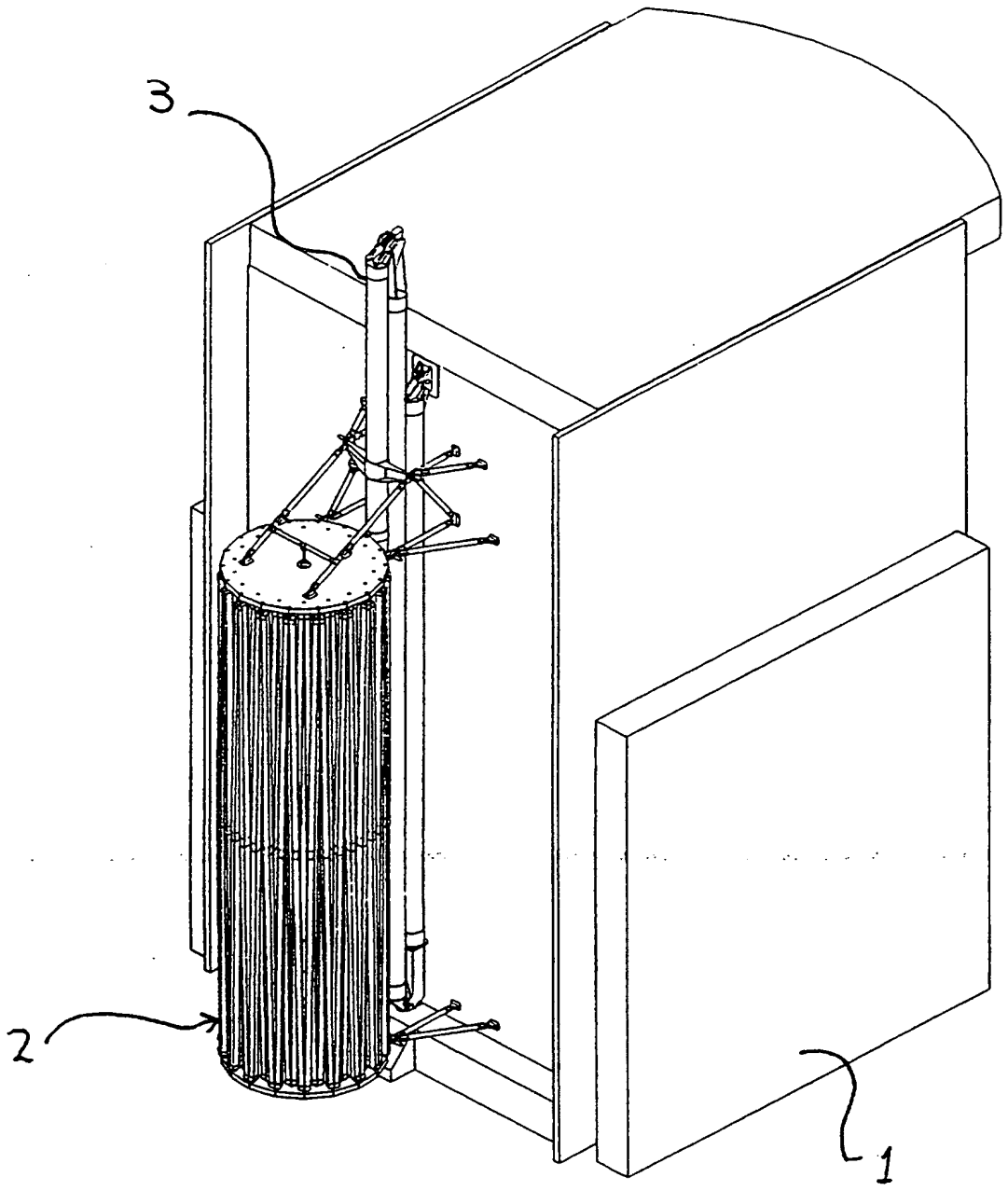


FIG. 1

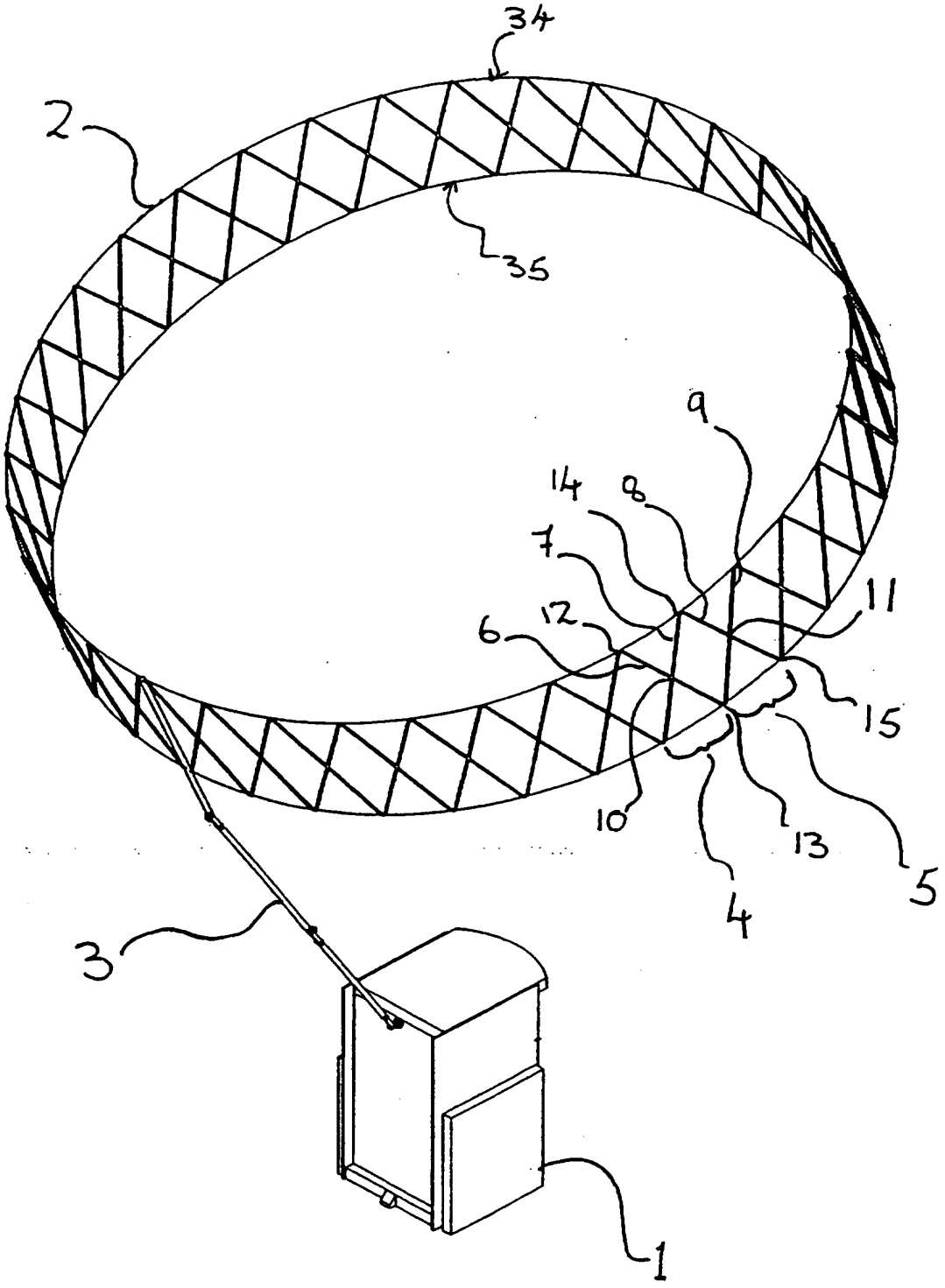


FIG. 2

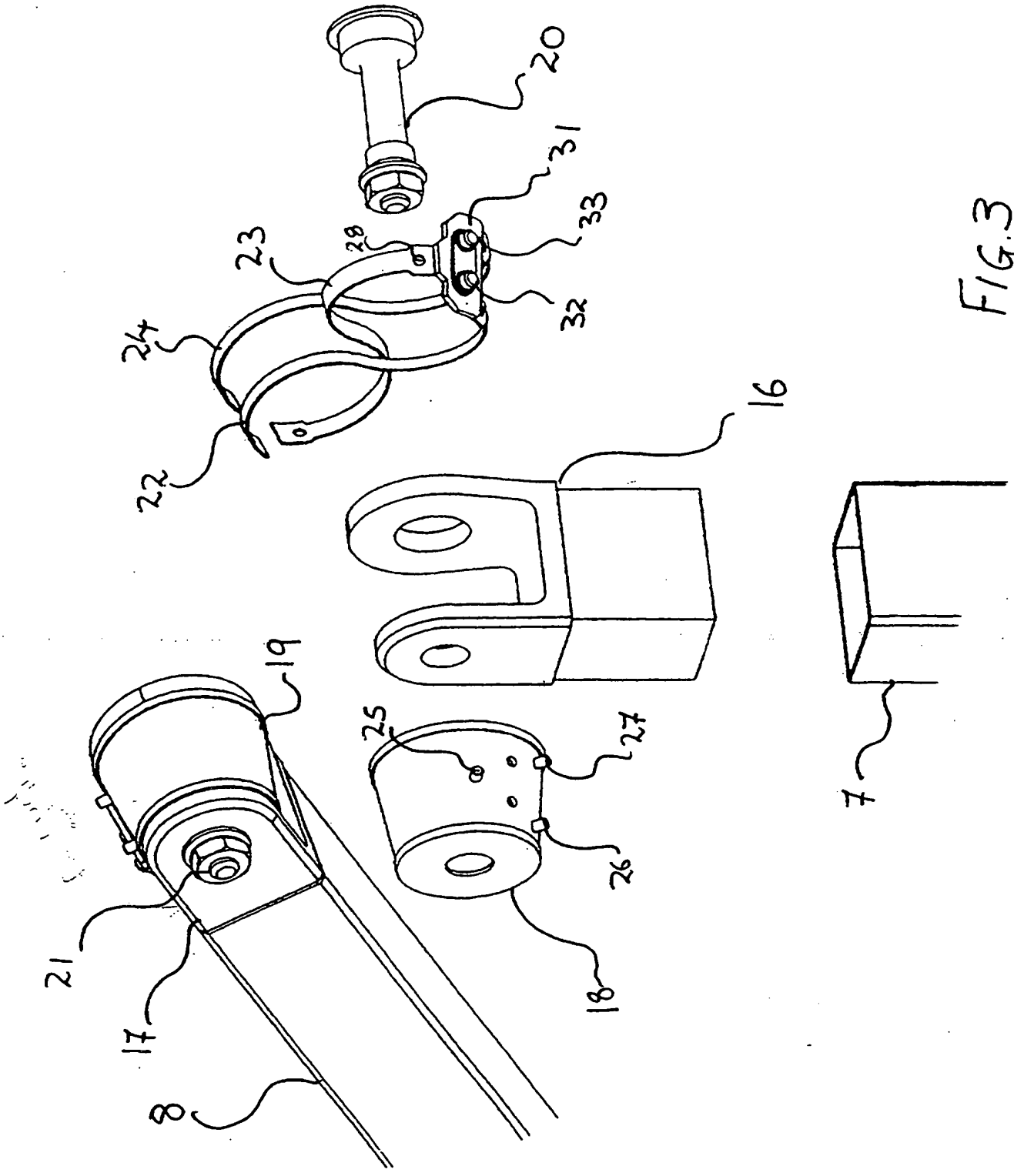
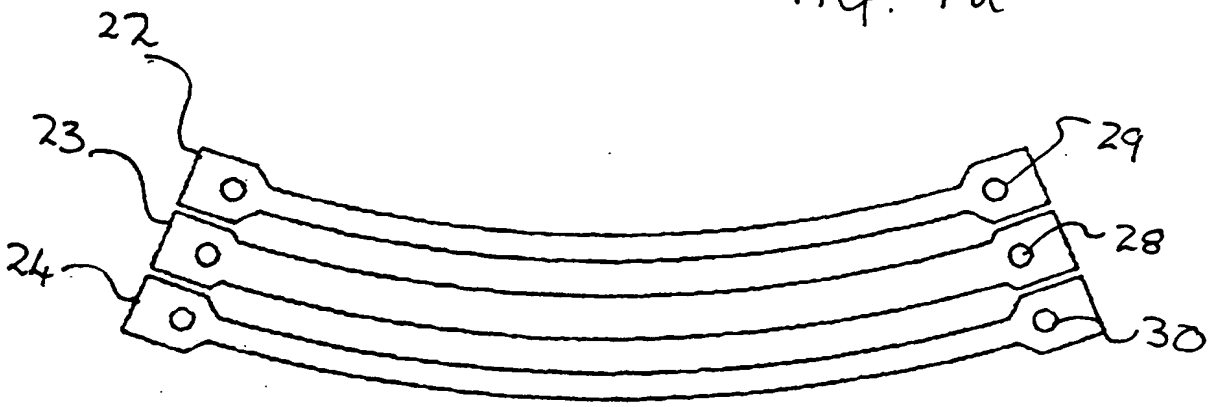


FIG.3

FIG. 4a



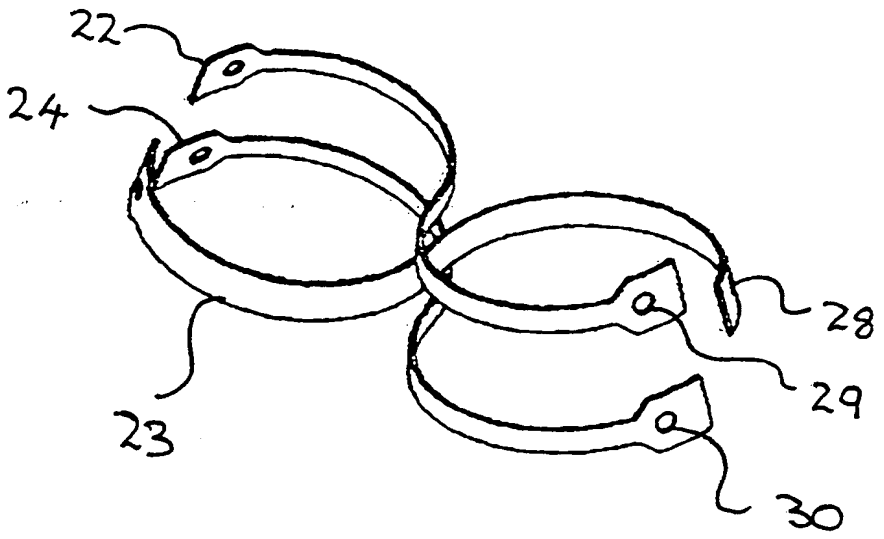


FIG. 4b

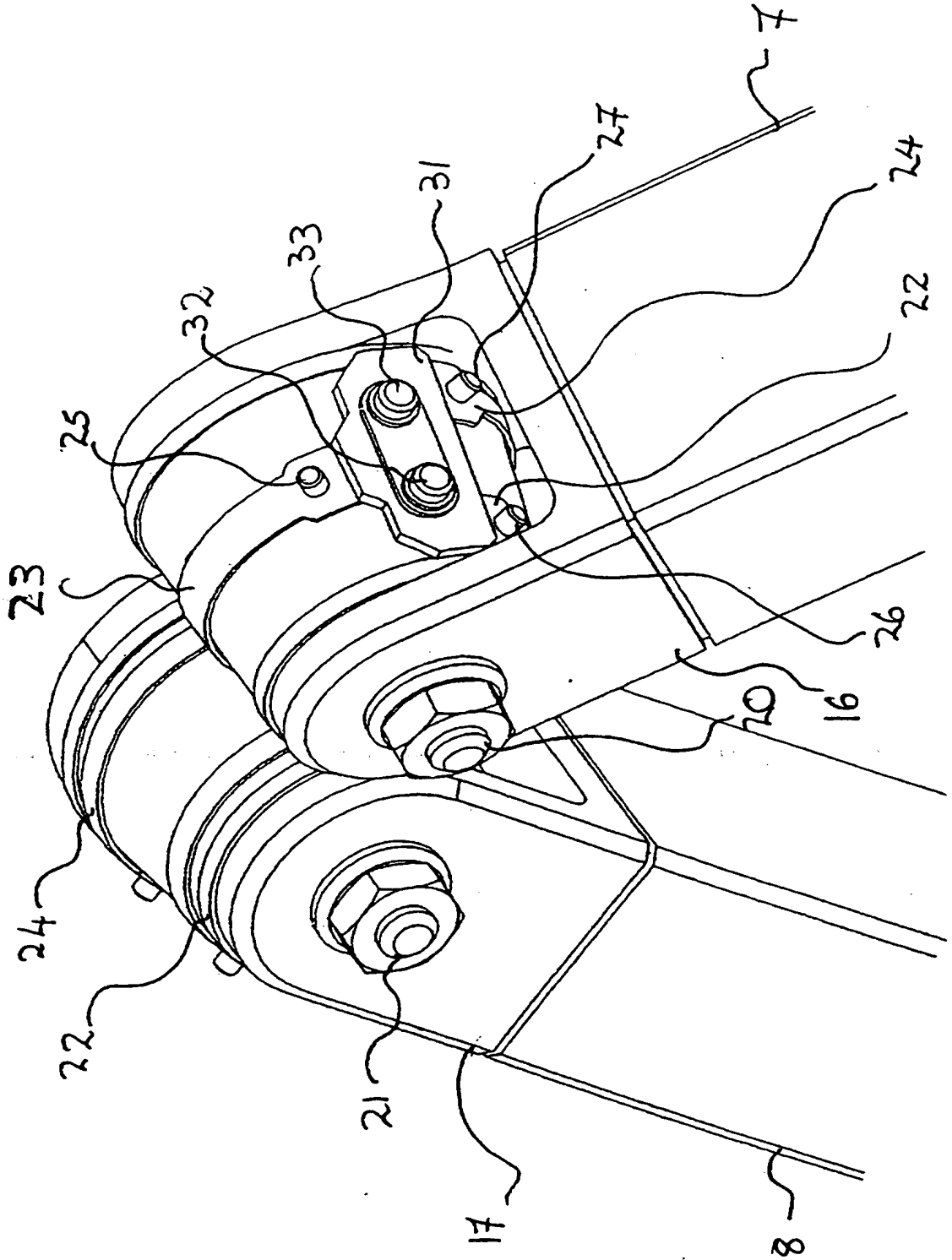


FIG 5

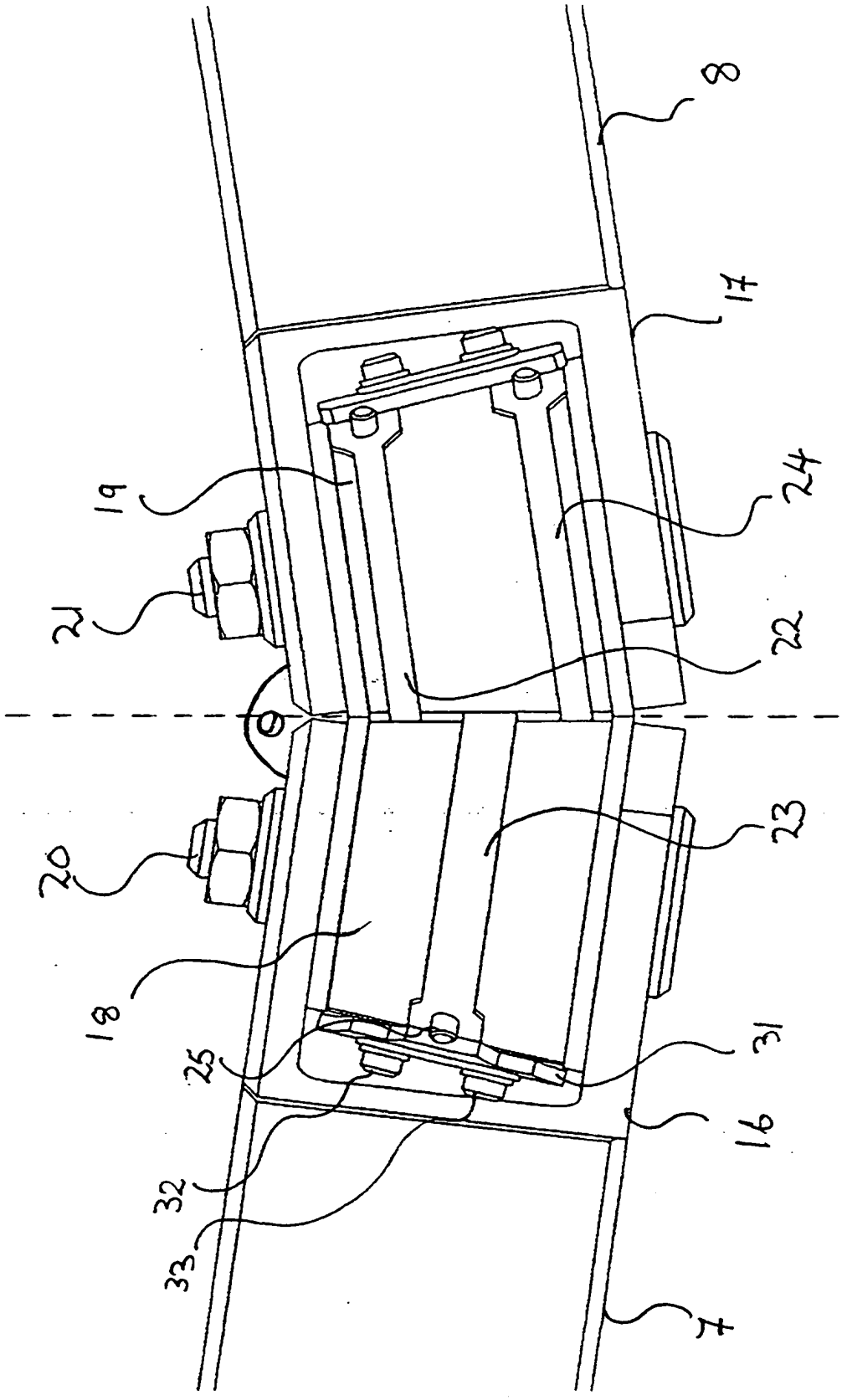


FIG. 6

EXPANDABLE SUPPORT RING

This invention relates to expandable support rings for deployable antenna reflectors.

Antennae are employed on, for instance, communications satellites in space to transmit and receive beams for mobile telephony. Advances in mobile telephony have resulted in a demand for communications satellites having antenna reflectors of large diameter, typically greater than five metres. To achieve this, the reflector has to be unfurlable. It has been proposed to attach an expandable support ring to the reflector, the ring comprising struts hinged together by gears. However, high frictional forces and backlash may be encountered with such gears.

The invention provides an expandable support ring for a deployable antenna reflector, the ring comprising a plurality of pairs of struts, linked to each other so that the ring can expand by pantograph action, respective hinge means for linking an end of each strut of each pair to an end of a strut of the adjacent pair, each hinge means including a pair of tapered surfaces which maintain rolling contact as the ring expands.

The invention provides an arrangement capable of low friction and low backlash during expansion.

Preferably the tapered surfaces are arranged so adjacent pairs of struts are inclined at an angle to each other, this angle remaining constant as the antenna is deployed. This

feature permits the struts to be connected in a ring without excess strain being put on the hinges and enables the ring to expand radially.

The hinge means advantageously includes at least one band which is attached to both tapered surfaces, and which is wrapped around the upper face of one of the tapered surfaces and the lower face of the other tapered surface, so that rotation of one tapered surface effects substantially equal and opposite rotation of the other tapered surface. This type of coupling enables each hinge to open symmetrically so that the ring expands uniformly.

The struts of each pair may be linked to each other at their mid points by means of a resiliently flexible pivot. The inclusion of flexible pivots enables the ring to be biassed to partly-expanded position.

The tapered surfaces may be of plastics material. This is advantageous over hinges having metallic surfaces, as contacting electric conductors can produce passive intermodulation (PIM) distortion on beams being transmitted or received by the antenna.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 is a simplified view of a communications satellite having a deployable antenna reflector and an expandable support ring constructed according to the invention;

Figure 2 shows the satellite of Figure 1, with the antenna reflector deployed and the support ring expanded;

Figure 3 is a partly exploded perspective view of hinge means of the support ring of Figures 1 and 2;

Figures 4a and 4b illustrate a means for coupling the tapered surfaces of the hinge of Figure 3;

Figure 5 is a perspective view of the hinge of Figure 3; and

Figure 6 is a plan view from above of the hinge of Figures 3 and 5.

Referring to Figures 1 and 2, a communications satellite, indicated generally by the reference numeral 1 is shown. The satellite has the usual components such as solar panels, feed horns etc. but these are not shown in these drawings for clarity.

The communications satellite 1 is shown in Figure 1 with a support ring 2 constructed according to the invention in a stowed position, ready for launch of the satellite. The support ring 2 surrounds an unfurlable antenna reflector, which is not shown in the drawings for clarity. The satellite 1 carries the support ring on an articulated boom 3, which is collapsed for launch.

In Figure 2, the communications satellite 1 is shown with its antenna reflector deployed. The boom 3 has been extended and the support ring 2 expanded so that the antenna reflector is unfurled and in a position suitable for the transmission and/or reception of signals. The arrangement of the support ring 2, and the mechanism by which it achieves this expanded position is described below.

The support ring 2 comprises a plurality of pairs, e.g. 4, 5 of struts 6, 7 and 8, 9 respectively, which are assembled to form a faceted annular ring. The struts of each pair are linked at their mid points by a flexible pivot e.g. 10, 11 etc, so that the ring can expand like a pantograph. The pivots 10, 11 are resiliently biassed so that the struts of each pair tend to open out so as to be perpendicular to each other. Thus, the ring 2 is biassed to a partly-expanded position, this biassing assisting the initial expansion of the ring as the antenna reflector is deployed.

Hinges e.g. 12, 13, 14, 15 are also provided, each hinge being arranged to link an end of each strut of each pair to an end of a strut of an adjacent pair. Hinge 14 is shown in more detail in Figures 3, 5 and 6.

Referring now to Figure 3, the top end regions of struts 7 and 8 of adjacent pairs 4 and 5 are shown. Each of the struts has a hollow end section, into which a bracket is slotted. Each of the brackets 16, 17 is arranged to house a tapered roller 18, 19. The tapered rollers 18, 19 are located in their respective brackets by means of respective bolts 20, 21 so that the rollers are capable of rolling relative to each other, but do not roll relative

to the struts to which they are attached. The rollers 18, 19 are connected to each other by means of bands 22, 23 and 24, which are shown in Figures 4a and 4b.

Figure 4a shows the bands employed to couple the tapered surfaces of the rollers 18, 19. The bands 22 to 24 are of different lengths and have different parallel radii. The central, wider band 23 is bent into an S-shape, as shown in Figure 4b. The adjacent bands 22 and 24 are also bent into respective S-shapes, but are of the opposite curvature to band 23. The curvature of the bands 22 to 24 enables them to be slid onto the rollers 18, 19 without buckling. Bands 22 and 24 are arranged to fit on the lower surface of the roller 18 and the upper surface of roller 19 while the wider band 23 is arranged to lie on the upper surface of roller 18 and the lower surface of roller 19.

Lugs 25, 26 and 27 are provided on roller 18, which lugs locate holes 28, 29 and 30 respectively on bands 22 to 24 to prevent slippage of the bands during expansion of the ring. The ends of the bands 24 are sandwiched against roller 18 by means of a fixing plate 31, the plate being fixed to the roller by means of bolts 32, 33 introduced through holes on the plate. A second similar plate and bolt arrangement (not shown in Figure 3) is employed to fit the bands to the roller 19. A fully assembled hinge mechanism is shown in Figure 5 and in the plan view of Figure 6.

The mechanism by which the ring expands will now be described with reference to Figures 5 and 6. On deployment of the antenna, a motor may be employed to initiate the expansion of the ring 2 by pulling out a strut from its initial stowed position. For

instance, consider that strut 7 is moved outwardly by the motor. The motion of strut 7 effects rotation of tapered roller 18 in an anti-clockwise sense as viewed in Figure 5, the strut moving out of the plane of the paper in Figure 6. Such a motion causes the S bands 22 and 24 on the upper face of tapered roller 19 to be pulled towards the lower face of tapered roller 18 and, consequently, clockwise rotation of roller 19 is instigated. Therefore, as viewed in Figure 6, rotation of roller 19 causes strut 8 to also move out of the plane of the paper.

Rotation of tapered roller 18 is matched by substantially equal rotation of tapered roller 19 in the opposite direction and, therefore, hinge 14 opens out symmetrically. The induced motion generated by the hinges is propagated along the ring and, therefore, the ring expands.

The degree of tapering of the surfaces of the rollers depends on the number of pairs of struts employed to form the ring. For instance, if 24 pairs of struts are employed, the angle, marked θ, between the struts has to be 165°. Consequently, the tapered surfaces are manufactured to permit this angle to be achieved and maintained in use. The broken line of Figure 6 bisects angle θ between the struts 7 and 8. As the hinge 14 opens, the line bisecting θ remains in the vertical plane (i.e. the plane perpendicular to the plane of the paper) subtended by the broken line. All of the hinges of the ring expand in a similar fashion. Thus, the tapered surfaces permit the pantograph, which is conventionally a linear expansion mechanism, to radially expand as the pantograph is extended. This feature enables uniform unfurling of the reflector to be achieved.

Cables may be provided between the ends of the struts, which cables form two parallel rings 34 and 35 when the antenna is deployed. The cables define the limit of expansion of the ring. The cables may be of synthetic fibre, such as Kevlar (RTM). The struts may be manufactured from pultruded plastics material and the brackets and tapered surfaces may be moulded from a composite material chosen to thermally match the struts and to be low in mass. The use of composite plastics material avoids the occurrence of passive intermodulation (PIM) distortion, which can occur between contacting electric conductors.

The bands may be made from a beryllium/copper alloy, and may be preformed in their S-configurations to provide sufficient torque to compensate for rolling friction or even to provide a self-deploying characteristic. Alternatively, just one band may be employed having a figure-of-eight configuration.

The invention permits a ring having a low-friction torque characteristic to be achieved due to the rolling contacts and backlash-free kinematics.

CLAIMS

1. An expandable support ring for a deployable antenna reflector, the ring comprising a plurality of pairs of struts, linked to each other so that the ring can expand by pantograph action, and respective hinge means for linking an end of each strut of each pair to an end of a strut of the adjacent pair, each hinge means including a pair of tapered surfaces which maintain rolling contact as the ring expands.

2. An expandable support ring as claimed in claim 1, wherein the tapered surfaces are arranged such that adjacent pair of struts are inclined at an angle, which angle remains substantially constant as the ring expands.

3. An expandable support ring as claimed in claim 1 or 2, wherein the hinge means includes a band coupling the tapered surfaces, the band being wrapped around the upper face of one tapered surface and the lower face of the other tapered surface, so that rotation of one tapered surface effects substantially equal and opposite rotation of the other tapered surface.

4. An expandable support ring as claimed in claim 1 or 2, wherein the hinge means includes a plurality of bands coupling the first and second tapered surfaces, at least one band being wrapped around the upper face of the first tapered surface and the lower face of the second tapered surface, and adjacent bands being wrapped around the lower face of the first tapered surface and the upper face of the second tapered surface, so that

rotation of one tapered surface effects substantially equal and opposite rotation of the other tapered surface.

5. An expandable support ring as claimed in any one of claims 1 to 4, wherein the struts of each pair are linked to each other at their centre regions by means of a resiliently biassed pivot.

6. An expandable support ring as claimed in any one of claims 1 to 5, wherein the tapered surfaces are of plastics material.

7. An expandable support ring for a deployable antenna reflector substantially as hereinbefore described, with reference to, or as illustrated in, the accompanying drawings.

8. A deployable antenna including an expandable support ring as claimed in any one of claims 1 to 7.

9. A spacecraft including an expandable support ring as claimed in any one of claims 1 to 7.

The Patent Office

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Application No: GB 9720994.4 **Examiner:** John Betts
Claims searched: 1-9 **Date of search:** 3 March 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): H1Q (QKC) F2K (K4B5, K4B9)

Int Cl (Ed.6): H01Q 1/08 1/12 1/28 F16H 21/00, 21/04, 21/02, 21/46 B64G 9/00

Other: On-line: WPI, CLAIMS, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	US5243803 (Mitsubishi)	
A	US4896165 (Mitsubishi)	

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